ICT Imaging Proposal
Skull and Innominate
Kennewick Man Skeleton
Proposal dated May 10, 2005

## Introduction

Plaintiffs propose to use Industrial Computed Tomography (ICT) technology to create dimensionally accurate replicas of the individual pieces of the skull and the right hip bone (innominate) of the Kennewick Man skeleton. This proposal has been developed in response to the concerns expressed by the government's representatives regarding the use of adhesives for mending broken or separated bones of the skeleton. If the use of adhesives is ruled out, some alternative must be found to create a permanently stable reconstruction of the skull to ensure that the configuration measured by all investigators is identical. The proposal described herein seeks to achieve that objective. If successful, it will also: (a) reduce the amount of handling of the original skull pieces during plaintiffs' studies of the skeleton and by future investigators; (b) allow us to visualize the embedded projectile point for purposes of more accurate identification; (c) permit both internal and external bone structural analyses of the skull and the innominate which are critical for determining the distribution of sediments within the endocranial cavity and for evaluating the projectile point; and (d) allow us to test the accuracy of the current reconstruction of the face, and if necessary adjust that reconstruction digitally and in replicas. The scanning process poses no threat to the bones.

1. ICT Scanning

The pieces of the skull and the right innominate will be scanned using a high powered non-invasive ICT scanner. ICT scanners are capable of extracting high-resolution images that are as much as ten times more accurate than those produced by a Medical Computed Tomography (MCT) scanner. Because ICT scanning provides a much higher degree of detail, substantially more data is generated for digital reconstruction of the skull and the projectile point than would be possible with MCT scanning. The technology used for industrial and medical scanners are substantially the same. The primary difference is that in the medical field there is a need to limit patient exposure to radiation, and consequently the resolution of the images is lower. In addition, with an ICT scanner, the specimens being scanned are rotated very slowly on a level turntable while the X-ray source and detector remain stationary (in MCT scanning the X-ray source and detector rotate while the patient remains stationary). ICT scanners make it possible to take exceptionally thin slices of data that translate into much finer detail than MCT. Once the scan data has been collected, it is processed to yield a graphic image of the data slices and is then translated into files that can be analyzed and used for rapid prototyping.

2. Digitalization (Development of STL Files)

In this step, the ICT slices of data are combined to generate three-dimensional computer models. This information conversion makes it possible to view images of the scanned bones from a multiple of different perspectives. The scanned/digitized bones can then be physically recreated through the process of Rapid Prototyping (RP).

3. RP Process

The RP process takes the 3D computer model (STL) that was developed during digitalization and converts the model into a series of stacked layers for "3D printing". In most cases these layers are approximately 0.1 mm thick. The layered model file is then sent to a machine that uses a photo polymer liquid plastic to lay down consecutive layers of plastic until the complete unit has been fabricated. This process was initially developed by the automotive and aeronautical industries to ensure the form, fit and function of manufactured parts that require a very high level of accuracy. It is hoped that applying this process to the Kennewick Man skull and innominate will allow accurate reproduction of the bone pieces and the embedded projectile point. The skull pieces can then be glued together to produce a reconstructed skull that can be measured without risk to the original. We propose to use the RP process to prepare replicas of the different skull pieces, the right innominate and the projectile point.

4. Casting

The plastic replicas produced by the RP process can experience some shrinkage, usually small, over an extended period of time. To develop permanent models that do not shrink we propose to make molds and casts of the RP replicas using high quality silicone rubber and Hydrocal Gypsum Cement. These molds and casts will be prepared by Mr. Steve Jabo, Museum Specialist at the National Museum of Natural History (NMNH), Smithsonian Institution, Washington, D.C. Mr. Jabo has done casting for the NMNH for 13 years and is considered an expert in the molding and casting of rare and fragile specimens. He also has had extensive experience creating molds from prototypes. Mr. Jabo will use a silicone molding rubber (Polytek TinSil 70-25 RTV silicone), TAP

Marine Grade Epoxy (314 Resin with slow 143 Hardener), and Hydrocal Gypsum Cement (FGR-95) to construct permanent molds and casts of the RP replicas of the Kennewick Man bones. The use of high-quality supplies will help to maintain the dimensional integrity of the casts.

Mr. Jabo will prepare two types of molds of the Kennewick skull. One set of the plastic skull pieces created through the RP process will be taken to the Burke Museum where they will be measured by Dr. David Hunt against the original bones to verify their accuracy. If they are accurate within an acceptable range of variation, Dr. Hunt will assemble the plastic pieces into a model of the complete skull. This model will be returned to the Smithsonian where it will be used by Mr. Jabo to create a mold of the reconstructed skull. That mold will be used to produce durable casts of the skull. The other set of plastic skull pieces will be used by Mr. Jabo to create molds of each individual piece of the skull. These molds can then be used to make casts of the pieces so that future researchers will be able to test the accuracy of Dr. Hunt's reconstruction of the skull.

Using the RP replicas of the projectile point, Mr. Jabo will create a mold that can be used to produce casts of the projectile point. He will also create molds and casts of the innominate pieces.

5. Transportation and Scanning Logistics

The pieces of the cranium (i.e., the cranial vault, midface, and two sections of the mandible) and pieces of the right innominate will be transported to the ICT scanning facility of Bio Imaging Research (BIR) located at 425 Barclay Blvd. in Lincolnshire, IL. Lincolnshire is located approximately 15 miles north of Chicago's O'Hare Airport. The

bones will be transported via commercial airline by either plaintiffs' representatives (i.e., Dr. Douglas Owsley and Mr. Roy Clark), or by an Army Corps representative. Transportation will be arranged so that a driver and vehicle will pick up the courier and skeletal pieces at the Chicago airport for transport to BIR's facility. Ms. Rebecca Snyder, NMNH's expert in 3D imaging, will arrive separately at BIR and will act as a consultant to ensure that all necessary data are collected and processed according to the desired needs and data standards.

BIR manufactures industrial CT scanners and provides scanning services to both the industrial and scientific communities. BIR also scans critical components of aircraft and other transportation items for the NTSB. Due to the classified research that BIR does for government agencies, it possesses a secure vault with access limited to only two individuals in the company. Once the Kennewick Man remains arrive at the BIR facility, they will either be prepared for immediate scanning or secured in BIR's vault for overnight storage.

Due to the high precision used in the scanning process (which as noted above produces many times more data slices than MCT scans), the scanning process will require one to two days in residence at BIR. Accordingly, it should be anticipated that two nights will be spent in Chicago. An experienced technician will complete the scanning in the presence of plaintiffs' representatives and the Army Corps' representative. In advance of the scanning session, tests will be conducted on a substitute human cranium, mandible, and innominate sent by Dr. Owsley to BIR. The purpose of these tests is to determine the safest and most appropriate procedures and scanner settings to be followed for scanning of the Kennewick remains.

Upon completion of the scanning, the Kennewick remains will be returned to the Burke Museum in the same manner as they were transported to Chicago.

6. Technical Experts

The scan data will be forwarded to Virtual Surfaces Inc. (VSI), at 832 E. Rand Rd. #16 in Mt. Prospect, IL, about 20 minutes south of BIR, for digital editing and STL file generation. During the data editing process, analyses will be conducted to determine if it is possible to digitally reposition the skull fragments that were glued in 1996.

When the editing process has been completed, the data files will be sent to Laser Modeling Inc. (LMI) at 600 Albion Ave. in Schaumburg, IL, for rapid prototyping.

Overall planning, scanning, editing and rapid prototyping will be coordinated by Point Data Marketing Inc. (PDMI), whose offices are located at 6791 Talmedge Drive, Sparks, NV. Mobile Scanning Lab. Inc. (MSLI), also of 6791 Talmedge Drive, Sparks, NV, will oversee the CT scanning, under the direction of PDMI, in conjunction with BIR. VSI will perform all digital editing and LMI will perform the rapid prototyping, again under the supervision of PDMI.

7. ICT and Prototyping Products

The scanning and prototyping processes will provide the following products that can be used to create molds of the scanned pieces and to generate data for research by plaintiffs and future investigators:

- two complete sets of RP plastic replicas of the different bone components of the skull
- two RP plastic replicas of the projectile point
- one set of RP plastic replicas of the different pieces of the right innominate

- two sets of raw CT scan data in TIFF format (one set for plaintiffs; one for the Army Corps)
- two sets of STL and ASCII files for all scanned items (one set for plaintiffs; one for the Army Corps)

8. Scheduling

The preferred time to have the skeletal pieces scanned at BIR would be late May or the first two weeks of June 2005. Such a schedule would allow time to complete analysis of the scan data and production of the RP replicas before the July 5-15, 2005 taphonomic study takes place. It is important that the skull and right innominate replica pieces be available for assembly by Dr. Hunt during the taphonomic study session. Dr. Hunt will glue one set of these pieces together to produce models of those two skeletal elements that are as complete as possible. To ensure that his reconstructions of these elements are as accurate as possible, Dr. Hunt will need access to the original specimens so he can refer to them for guidance.

9. General Comments

It is hoped that the casts to be created from the RP replicas will be accurate enough to provide many of the measurements needed by plaintiffs' study team and other investigators. Even so, it will still be necessary for investigators to have access to the original bones. Among other things, they will need to refer to the original bones to help locate key measurement landmarks that may be difficult to find on the cast models, to verify for themselves that the models are accurate, and to obtain certain types of nonmetric data. However, if the replication process is successful, it will reduce substantially the need for future handling of the original bones. Moreover, it will eliminate the need to glue together the various pieces of the actual cranium, mandible and

innominate. Finally, the replication process proposed here will permit investigations that would not be possible otherwise (e.g., analysis of the endocranial vault, digital repositioning of the malars, etc.).

Digital extraction and high resolution production of an accurate replica of the embedded projectile point will reveal its size and structural details, which will aid in its identification. Computer aided examination of the right innominate will provide information needed in order to interpret the pathology and pathway of the projectile.

Although plaintiffs cannot guarantee in advance the ultimate accuracy of the RP replicas and the casted models to be created as described in this proposal, the prospects are very favorable. These techniques have reportedly been used in other situations with a high degree of success. Plaintiffs are unaware of any circumstances that would preclude their successful application to the Kennewick remains.